чильного стана, минуя термическую обработку на отдельных агрегатах.

OPTIMIZATION OF METALLOGRAPHIC PREPARATION FOR THERMALLY SPRAYED COATINGS USING TAGUCHI METHOD

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The aim of the investigation was to develop reliable and reproducible metallographic preparation procedures tailored to different classes of coatings that reveal their true microstructure. Statistical design of experiments is used to optimize the metallographic preparation procedure. Polishing quality is discussed with respect to the formation of voids (pullouts) mainly.

The experiments were carried out on different ceramic and metallic coatings deposited by the Atmospheric and Vacuum Plasma Spray (APS and VPS) and on cermet deposited by High Velocity Oxygen Fuel (HVOF) processes.

A variable speed grinding/polishing machine (Ecomet 4000) with controlled power head (AutoMet 3000) was used for sample preparation. Image analysis was performed using a Nicon Optiphot Optical Microscope on the samples after each test, to measure void percentage (porosity and pullouts).

A Taguchi-style, fractional L8 design of experiments was employed to evaluate the effect of sample preparation variables on the polishing quality. Seven parameters known or expected to directly influence the polishing quality were selected. Statistical analysis was accomplished with StatGraphics software. Eight tests within the matrix and then three additional tests outside of the matrix space were performed, one by one, on the same samples.

For ceramic and cermet coatings, the sample integrity and final polishing stages were mainly investigated. The parameters chosen for the test were: polishing wheel rotational speed, holding wheel (head) movement direction (combination of contra and complimentary) and sample positioning (parallel or perpendicular to the wheel movement), applied pressure and polishing time. The effect of the epoxy used for sample mounting and cloth condition (used versus new) was also taken into consideration. For metallic coatings, all the sample preparation stages (planar grinding, sample integrity and final polishing) were investigated. Use of finer versus coarser abrasives, polishing wheel rotation speed, applied pressure and polishing time were studied.

As an example, the effect of the factors in decreasing order of importance for different ceramic coatings is presented, Fig. 1.

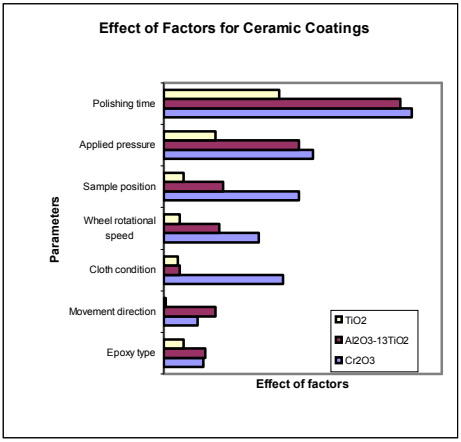

Fig. 1. - Effect of factors for ceramic coatings.

For the ceramic coatings, lower void percentage is observed when using higher values of polishing time and pressure. Sample positioning on the holding wheel and grinding/polishing wheel rotational speed are also important but exhibit lower influence. Higher rotational speed and positioning of the samples perpendicular to the holding wheel movement result in less coating damage during sample preparation.

Void formation seems to be lower when using new cloths (versus used ones). Holding wheel movement direction and the type of epoxy used for mounting samples are not significant to the polishing quality.

Polishing conditions are strongly dependent on the microhardness of the coating. In general, as for ceramic coatings, the coatings with higher microhardness are more sensitive to polishing conditions. For example, for Cr2O3 coatings with the highest microhardness (1000 HV0.3), the effect of the factors is slightly superior to Al2O3-13TiO2 coatings with a microhardness value of 938 HV0.3 and much higher than for TiO2 coatings with relatively low microhardness (747 HV0.3). A 20-30 % increase in polishing time, a 20–40 % increase in polishing pressure and 30–50 % increase in polishing wheel rotational speed results in 20-50 % reduction in void percentage. As an example, the cross-section of TiO2 coating polished with standard (left) and new (centre) procedures, is presented, Fig. 2.

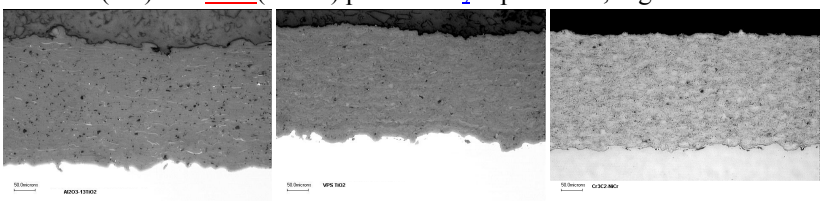

Fig. 2.- Cross-section of TiO2 and Cr3C2–NiCr coatings polished with standard (left) and new (centre and right) procedures.

For the analyzed cermet coatings with moderate microhardness (890 HV0.3), the effect of all the factors is lower than that for ceramic coatings. Void formation is mostly influenced by sample positioning on the holding wheel. Less coating damage is produced when positioning the sample perpendicular to the head movement direction. As an example, the cross-section of the Cr3C2–NiCr coating polished using new polishing procedure is presented, Fig. 2 (right). When using a new polishing procedure for ceramic and cermet coatings, void percentage decreases below 1.2 %.

For the metallic Ti-6Al-4V coating and net shape formed samples, less coating damage is produced when using finer abrasives versus the coarser ones. In that case, polishing time must be increased to ensure the removal of scratches and of material damaged at previous polishing steps or smeared over the voids. Cross-section of the Ti-6Al-4V net-shape formed sample, using different polishing procedures, is presented, Fig. 3. When using a new polishing procedure (utilization of finer abrasives versus coarser ones and increased polishing time, slightly increased wheel rotation speed and moderate polishing pressure) for both the Ti-6Al-4V coating and net shape formed samples, void formation decreases from 3.5 to 1 and 1.5%, respectively.

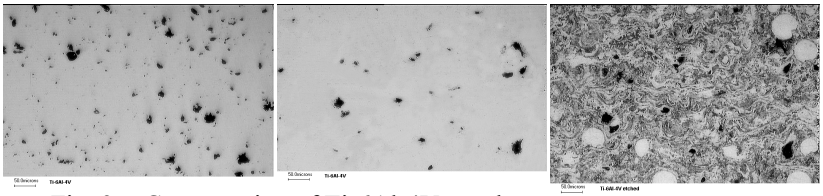

Fig. 3. - Cross-section of Ti-6Al-4V net shape formed sample polished with standard (left) and new (center and right) procedures.

To verify the presence or absence of smearing while polishing metallic coatings and net shape formed samples, etching with a mixture of 5 % HNO3, 10% HF and 85% H2O was performed. Difference in void percentage on non-etched and etched samples is within the error of the experiment. As an example, the microstructure of the same area of non-etched and etched the Ti-6Al-4V net shape formed sample is presented, Fig. 3 (center and right).

The trends observed in the presented study can be successfully used for different classes of thermally sprayed coatings when developing their polishing procedure using various polishing equipment and supplies.